APPENDIX C

REASONABLE WORST CASE ANALYSIS
DIRECT INJURY TO BIRDS

REASONABLE WORST CASE (RWC) ANALYSIS
DIRECT INJURY TO BIRDS

1.0 INTRODUCTION

This technical memorandum summarizes the assessment of the potential for direct injuries to birds due to exposure to mercury released from the Site. Birds are an important component of the ecological systems within the Lavaca Bay estuary. Bird populations in the estuary are both numerous and highly diverse. In the Lavaca Bay area, direct exposure of bird populations to mercury has been confirmed in past studies by Gamble et al. (1994) and Shultz et al. (1994, and as revised in Shultz, 1997). Further, mercury accumulation in important prey species for birds has been documented in both current sampling and in historical monitoring events. These studies were conducted from 1970 to 1996 by the Texas Department of Health (TDH, 1998), Reigel (1990), Presley et al (1993), Shultz et al. (1994), Locarnini and Presley (1996), and as part of the remedial investigation (Alcoa, draft RI).

In Lavaca Bay, injury to birds may occur as the result of either:
1. Exposure to mercury in sediments and surface waters or through ingestion of contaminated prey items in the food web; and
2. Habitat losses resulting from remedial activities.

Indirect impacts to birds from habitat destruction or elimination due to remedial activities can be defined as habitat service losses to birds (and other resources) and evaluated at the habitat level. That is, the area, or quantity, of habitat impacted is measured directly and the loss of the services of these habitats to resources such as birds compensated through the services provided by replacement habitat(s). This approach ensures that injuries in common among resources within an interrelated ecosystem, are not double counted in the assessment process. Indirect impacts to birds due to such habitat losses, therefore, will be addressed in the Benthos and Terrestrial Resource injury assessments.

This technical memorandum is focused on the assessment and quantification of potential injuries to birds associated with exposure to mercury, using a reasonable worst case (RWC) approach. Mercury exposure may impact bird populations by decreasing survival and reproduction. For this Site, studies indicate the primary pathway for exposure of birds to mercury is through ingestion of contaminated food (Alcoa, Draft BLRA). Another ingestion pathway is the incidental ingestion of mercury-contaminated sediment and water, however, this pathway has been evaluated in the ecological risk assessment and determined to be very small in comparison to the prey ingestion pathway (Alcoa, Draft BLRA). Accordingly, the evaluation and assessment of injury to birds is, like that for finfish resources, principally concerned with the biomagnification (i.e., the biological transfer) of mercury through the food web.

The mercury-contaminated habitats within the Site (e.g., low marsh/mudflats; oyster reefs; and open water sediments) are locations where prey items of both finfish and birds become contaminated with mercury. Therefore, these habitats can be evaluated to determine whether they are providing full service as the foodweb base supporting bird and fish populations, or, whether they are providing reduced food services because the prey's mercury concentrations in these areas are high enough to cause potential injury. This provides a common basis for evaluating the potential injuries to birds and finfish due to mercury levels in these habitats. Assessment of resource injuries at the habitat level allows identified injuries to be quantified as ecological service losses from these habitats, which guides and facilitates planning for the restoration of habitats required to offset those losses. In this instance, a habitat-level approach to evaluating injuries to birds also permits appropriate comparisons between the RWC injury assessment for birds and the results of the RWC injury assessment for finfish resources. For the habitats at issue, this allows the Trustees to base restoration requirements on whichever resource, finfish or birds, is determined to have the greater potential injury as a result of the contamination present, using the RWC approach.

The first step under the above outlined approach was to determine whether the potential injury to bird populations exceeded that of corresponding fish populations for each habitat type/location. The habitat types and locations depicted in the remedial investigation habitat mapping (Alcoa 1997a) were used. To support comparison to the injuries determined for finfish, the Trustees developed estimated sediment concentrations for mercury that would represent different levels of potential injury to birds via ingestion of prey items associated with the estimated sediment concentrations for each habitat type/location.

For finfish resources, exposure to mercury was assessed based on data and modeling of the bioaccumulation of methyl mercury in finfish resources from prey ingestion. Effects of this exposure on finfish resources were assessed based on critical tissue concentrations (identified by reviewing the scientific literature) which could then be related back to sediment concentrations underlying the bioaccumulation analyses. For finfish, and their prey items, available data on mercury contaminant levels in Lavaca Bay facilitated this assessment (Alcoa, 1998).

For birds, there is no large database available for mercury tissue levels within the Site. However, previous studies and scientific literature provided a basis for evaluating potential effects to birds from different concentrations of mercury in prey. No-observed adverse effect level (NOAEL) and low-observed adverse effect level (LOAEL) in the diet of representative bird species, based on both prey concentrations and anticipated doses through feeding, were identified and were used to assess exposure and potential injuries to birds. For each habitat type/location, mercury sediment concentrations corresponding to the NOAEL and LOAEL levels of exposure through the diet of birds were identified based on the bioaccumulation in prey (based on the finfish RWC assessment) and dosing assumptions for birds, assuming an RWC feeding scenario. Because injuries to birds were not directly measured but were indirectly assessed under the above approach, the following general assumptions were also used in the evaluation:

1. bird populations are exposed to excess levels of mercury;
2. the principle route of exposure is through bioaccumulation;
3. the principle form of mercury to which birds are exposed through diet is methyl mercury;
4. exposure can be quantified by estimating a dose through measured concentrations of mercury in principle prey species from an exposure area; and
5. injury can be assessed based on available information on dose-response modeling.

This approach resulted in the identification of mercury sediment concentrations for each habitat type/location that represented a risk of adverse effects to birds based on exposure to mercury through the diet of representative bird populations. These were compared to mercury sediment concentrations identified as resulting in injury to finfish resources and, for each habitat type/location, the lower of these mercury sediment concentrations were used to represent injury for both resources. In this manner, the greater likelihood or degree of injury or loss to resources due to biomagnifications of mercury through the food web provided the basis for assessing and quantifying the ecological service losses for each habitat type/location.

Where the fish injuries exceeded that predicted for birds, for the comparable habitat type or location, the Trustees concluded that habitat restoration scaled to address the assessed fish injury would also compensate for the lesser injury to birds. In this instance, further action to quantify the bird injury was not necessary. If the bird injury assessed for a particular habitat type or location had exceeded the injury assessed for fish, further quantification of the bird injury for that habitat or location would have been necessary. For every habitat type/location at issue, using the above described approach, the Trustees found that the mercury sediment concentrations resulting in assessed injuries to finfish resources were lower than those which would result in injuries or losses to birds. Accordingly, sediment concentrations, and the injuries to finfish corresponding to these concentrations identified in the injury assessment for finfish, were used to scale the habitat restoration or creation required to compensate for injuries to both resources.

The approach outlined above is conservative and is an RWC approach to assessing resource injuries attributable to the Site (see RWC Concept Memorandum).

2.0 METHODOLOGY

The methodology presented here addresses the potential injuries/service losses for birds via bioaccumulation and ingestion of contaminated prey. The specific steps followed for evaluating extent and severity of potential injury were:

1) <u>Identify indicator species for quantifying potential injury to birds</u>

The RWC method for birds employed the selection of representative groups or guilds with species likely to have the highest potential exposure to injurious levels of mercury contamination, namely shorebirds and wading birds. The criteria used to determine the potential for higher exposures included factors such as residency, home range and feeding ecology. Injury to other, less exposed species was lower and therefore accounted for as a result of quantification of injury for the higher exposed populations.

2) <u>Identify the important prey species for birds in a particular food web and assess exposure through bioaccumulation.</u>

Data collected primarily through the remedial investigation was used to determine pathways for potential exposure. Since there are a number of environmental factors that affect mercury bioaccumulation (i.e. factors that affect methylation as well as habitat differences that affect the accumulation and transfer of mercury in food webs), the objective was to understand exposure risk associated with specific habitat types and locations. The locations or subareas selected as exposure areas were representative of the habitats important for the indicator species.

3) Identify appropriate threshold values for toxic effects from exposure to mercury

Toxic effects threshold information (i.e., toxicity reference values or TRVs) was reviewed in Problem Formulation component of the Baseline Risk Assessment Report (Alcoa, draft BLRA). This information was used to identify locations with elevated prey concentrations sufficient to pose potential injury to indicator species and estimate the potential severity of injury to bird populations.

4) Develop a quantitative relationship between mercury concentrations in sediment and prey items for representative bird populations

Where exposure modeling and dose-response information existed that suggested a particular bird population was at risk, a habitat-based sediment threshold effect level was calculated based on dietary effects levels for that species. The sediment-threshold effect level was based on data collected on prey-sediment studies, conducted as part of the remedial investigation and ecological risk assessment. The purpose of this data was to establish a relationship between mercury concentration in surface sediment and associated bird prey concentrations that posed injury. The objective was to quantify this relationship by habitat type and location.

5) Compare sediment-effect levels for birds to corresponding sediment-effect levels for fish by habitat type/location

Injury associated with bioaccumulation was assumed to be either the injury to bird or fish populations depending on which injury was greater. Therefore, on a habitat/location basis, the sediment-effect threshold levels were compared directly as a measure of relative injury. For fish, the selected sediment effect levels (See Appendix B) were:

Low marsh habitats:	NOAEL = 0.7 ppm;	LOAEL = 1.3 ppm;
Oyster reef habitats:	NOAEL = 0.83 ppm;	LOAEL = 1.7 ppm;
Open water habitats:	NOAEL = 2 ppm;	LOAEL = 3 ppm;

6) If sediment effects levels identified for birds are lower than those identified for finfish, the potential bird injury is greater than the potential injury to finfish and is used to approximate the areal extent of sediment injury within habitats with surface contamination above the target threshold value

For those bird populations within a particular habitat with potential injury greater than fish, the areal extent of mercury concentrations in surface sediments was calculated for appropriate threshold concentrations determined in step 2. Consistent with the overall approach for calculating benthos injury, areal extent was calculated separately for marsh, oyster reef, and open water (unvegetated subtidal sediment) habitats.

7) Estimate severity of injury or loss of services (LOS) for each habitat area exceeding selected threshold values

LOS was estimated, based on pertinent studies in the published literature that describe the degree of adverse effects associated with various concentrations of mercury in the diet of birds or calculated exposure levels. A separate estimate was made for each threshold for the acreage of sediment within a habitat at each LOS level.

8) Estimate service losses for bioaccumulation

Data on the extent, temporal duration, and severity of potential injury/service losses for birds was used to calculate service losses for bioaccumulation.

In addition to the RWC injury assessment, bird surveys were conducted in the spring of 1997 in the potentially affected habitats of Lavaca Bay near Alcoa's Point Comfort Operations. These surveys provided data on the occurrence, abundance, and habitat relationships of shorebirds and wading birds, and incidental observations of nesting success. Results were used for a qualitative comparison with predictions of the severity of effects from Step 7. The study also provided data useful for restoration planning purposes.

2.1 Selection of Indicator Species for Assessing Injury

This section presents a summary of the rationale used to select representative receptors (species) for quantification of potential injury to birds in Lavaca Bay. This process is similar to that undertaken for the ecological risk assessment of the Remedial Investigation (Alcoa, Draft RI).

For purposes of reasonable worse case (RWC) analysis to bird receptors, injury was quantified for species determined to be at greatest risk from exposure to mercury. A qualitative analysis that scales injury to bird species of lower risk was completed, assuming that these species had less mercury exposure than the receptor species selected for quantitative injury determinations. The objective of the RWC approach was to quantify injury to particular habitats used by bird receptors with the intent to restore service losses associated with these habitats. This approach is considered both reasonable and conservative.

Candidate receptor species (representative species) were selected through an evaluation of feeding ecology, seasonal abundance/residency, and foraging patterns (foraging habitats, foraging range, etc.) of birds inhabiting Lavaca Bay. This evaluation begins with a review of the feeding guilds, and then evaluates birds within each guild to determine their appropriateness for consideration as receptor species.

Injury to birds is largely a function of their exposure to mercury through ingestion of various prey items that constitute their diet. For this reason, the feeding habits of birds are expected to be a key factor for determining a species potential exposure to mercury and their appropriateness as a receptor for RWC analysis. Existing data on levels of mercury concentrations in the tissues (i.e., liver and eggs) of some birds species is available (USFWS 1994a), and factored into the selection of receptor (representative) species. Toxicological sensitivity data is not available for bird species found in Lavaca Bay (Alcoa, Draft BLRA), thus sensitivity was not used in the receptor selection process.

2.1.1. Guilds

For the purposes of RWC analysis, bird guilds were defined largely by the criteria of diet and foraging strategy.[1] Candidate receptor species were selected from these guilds based on exposure factors such as the size of their foraging area (a part of foraging strategy), and seasonality of area use, including breeding. Each of these criteria are discussed below:

Diet: Mercury concentrations are known or expected to be greater in the higher trophic levels of aquatic vertebrates and invertebrates, than in aquatic plants or terrestrial-based prey items (Alcoa 1996). Mercury is biologically methylated under anoxic conditions typical of many aquatic sediments (e.g., Lavaca Bay). It is then biomagnified up the food chain as a result of normal energy flow. For inorganic mercury, exposure of invertebrates through their close contact with and foraging activities in aquatic media (sediments, water) results in enhanced accumulation of inorganic mercury residues, with trophic transfer also occurring as a result of natural energy flow to the higher trophic level vertebrate species, such as the fish and birds in Lavaca Bay. Therefore, it is expected that the proportion and form of mercury uptake for a fish-eating bird will differ from the proportion and form of mercury uptake of a bird specializing on invertebrates. Consequently, guilds were separated by whether the member birds species specialized on foraging for fish, invertebrates, or a combination of both.

Because the focus of the bird RWC is on service losses from habitats within Lavaca Bay, it was presumed that carnivorous (fish, invertebrate-eating) bird species consuming upper trophic level prey (fish), or invertebrates, from Lavaca Bay will be exposed to higher levels of mercury than bird species foraging in terrestrial environments. Accordingly, omnivorous aquatic birds that feed on both plant and animal matter, or herbivorous birds that feed only on plant matter, were both presumed to have reduced mercury exposure potential and were not further considered in the bird RWC receptor analysis.

Foraging Strategy: The foraging strategy of bird species includes foraging habitat and the size of its foraging range. Species that forage along shallow (0–1 feet deep) shorelines are likely to have narrow linear foraging habitats (e.g., shorebirds) compared to species that forage in deeper water (2–40 feet deep), where foraging activity is not concentrated in one part of Lavaca Bay (e.g., terns). At Lavaca bay, bird species with small foraging ranges that are fully or partially within the Closed Area (the area of the bay where the highest concentrations of mercury have been measured), are likely to be at greater risk from mercury exposure than species with larger foraging ranges that extend outside the Closed Area. Some shorebirds, such as herons, may concentrate their foraging activity at a number of nearshore habitats, including both the Closed Area, as well as areas outside of Lavaca Bay. Nevertheless, for the purposes of logical guild structuring, nearshore vs. bay habitat was used as the primary criteria for separating feeding guilds.

Seasonality: Bird species that inhabit Lavaca Bay year-round are more likely to be exposed to elevated levels of mercury on a longer-term basis (i.e., chronically) than migrant bird species.

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[1] In evaluating foraging strategies and defining guilds, "nearshore" was defined as the shallow water areas along the edge of *Spartina* marshes and shorelines, while "bay" was defined as the open water areas of Lavaca Bay.

Because ecologically relevant toxicological effects related to mercury and methyl mercury exposure relate primarily to reproductive success, there is likely a greater exposure potential for breeding resident bird species. Moreover, breeding birds, especially those that defend breeding territories, tend to have small foraging ranges that are concentrated around the nest site during the breeding season (Pettingill 1970). Mercury exposure is greatest if nesting occurs within or near the Closed Area.

Based on the aforementioned criteria, the following seven foraging guilds were developed and evaluated in the RWC receptor selection process:

-- Fish-eating birds using shallow (0–1 feet deep) nearshore bay habitats (including estuarine marshes and shorelines);

-- Fish-eating birds using deeper water (2–40 feet deep) bay habitats;

-- Invertebrate-eating birds using nearshore bay habitats;

-- Invertebrate-eating birds using deeper water bay habitats;

-- Combination fish/invertebrate-eating birds using nearshore bay habitats;

-- Combination fish/invertebrate-eating birds using deeper water bay habitats; and

-- Raptors.

Each of these feeding guilds are described in greater detail below.

Fish-Eating/Nearshore

This guild represents bird species that feed predominately on small fish (such as gobies and killifish) in shallow, nearshore habitats (such as *Spartina* marshes, oyster reefs, and rocky shorelines). Fish occurring in shallow water habitats, especially shoreline marshes, potentially have a greater exposure to mercury because of the increased levels of mercury methylation expected in these environments. Small terns will occasionally feed in nearshore habitat, and 75–98 percent of the diet of herons and egrets feeding in nearshore Florida estuarine habitats (Recher and Recher 1980) is comprised of fish.

The belted kingfisher is probably the best representative of this guild in Lavaca Bay. Kingfishers feed predominately on fish in the 6–12 cm range (Davis 1982), and defend relatively small linear (shoreline) feeding territories which are actually larger during the breeding season (1,030 m) than the non-breeding season (390 m) (Davis 1982). Kingfishers are common during the winter at Lavaca Bay (Alcoa 1995), and they are known to breed in the vicinity of the Alcoa site. Belted kingfishers have been observed in the Closed Area perched in trees along the edge of the sea cliff area west of Cox Point. However, because the belted kingfisher is relatively uncommon at the site most of the year, it is a poor receptor for natural resource damage assessment when compared with species in other guilds.

Fish-Eating/Bay

A wide variety of piscivorous (fish eating) bird species occur in Lavaca Bay as a result of the abundant fish resources present. Piscivorous species in the Bay include gulls, terns, skimmers, pelicans, cormorants, loons, and grebes. These birds feed on the abundant populations of gulf menhaden and anchovies found in Lavaca Bay (Pattillo et al. 1995), as well as the small bay squid (for practical reasons, squid has been included under the category of fish). These bird species are discussed below according to their taxonomic group.

Gulls, Terns, and Skimmers

Thirteen species of gulls and terns, including the black skimmer, have been recorded at Lavaca Bay (Alcoa 1995). Eight of these have been found to be common in one season or another, but only the laughing gull, Caspian tern, royal tern, Forster's tern, and black skimmer are common year-round residents. All also breed on Dredge Island 3, approximately 3 km outside the Closed Area, and many roost throughout the year on Dredge Island 2 within the Closed Area (Alcoa 1995).

Terns and the black skimmer feed on fish, shrimp, and squid (the Forster's tern also feeds on flying or floating aquatic insects in freshwater habitats). In Lavaca Bay, these bird species are likely to feed on gulf menhaden and bay anchovies (Pattillo et al. 1995). Paralarval bay squid, an abundant cephalopod in Matagorda Bay (Pattillo et al. 1995), may also be important to terns.

Because terns and gulls feed in open water areas of large bays, large river systems, and oceans, these species likely have relatively large feeding ranges, although at the site feeding during the nesting season is probably close to Dredge Island 3.

The laughing gull, black skimmer, and Caspian, royal, and Forster's terns occur on-site year-round, breed in the vicinity of the Closed Area, roost within the Closed Area, and feed on fish species potentially contaminated from exposure to mercury. Elevated mercury concentrations have been found in eggs of some species collected within Lavaca Bay (Alcoa 1996; King et al., 1991). Any of these species would make a good candidate receptor species (the ecological risk assessment focuses on the Forster's Tern).

Pelicans

Two species of large fish eating birds, the white and brown pelican, occur in Lavaca Bay. The Gulf of Mexico brown pelican's diet is comprised of 90–95% menhaden (Palmer 1962). Brown pelicans are found year-round in Lavaca Bay. White pelicans, however, are more seasonal and totally absent during the summer breeding season. Although brown pelicans are conspicuously present on the piers, dolphin posts, and light buoys near the Alcoa plant, they do not occur there in large numbers. They are presumed to have large foraging ranges and do not nest in Lavaca Bay. Brown pelicans, however do nest in adjacent Matagorda Bay but concentrations of mercury have not been found in their eggs (USFWS 1994a), suggesting pelicans do not ingest large amounts of mercury in Lavaca Bay. Consequently, pelicans were not selected as a candidate receptor to represent this guild.

Other Fish-Eating Birds

Other piscivorous birds that forage in the open water of Lavaca Bay include the common loon, grebes, cormorants, and the osprey (Alcoa 1995). None of these species are common year-round (Alcoa 1995). The common loon is common as a winter resident (Alcoa 1995). Pied-billed grebes nest in the vicinity (Alcoa 1995) and possibly within the Closed Area, but are only common during the fall and winter (Alcoa 1995). Other grebes are not common at any time of the year. Double-crested cormorants are common in the spring, fall, and winter months, but do not nest in the region, while olivaceous cormorants and osprey are uncommon all year. There is no information on winter diets of common loons. During the breeding season in Canada, they apparently prefer yellow perch (in the 10 gram - 250 gram size range) (Barr 1973 as reported by McIntyre 1986 and Barr 1986).

Compared with terns, the species in this group are not good candidates as receptors because of their seasonal or uncommon occurrence in Lavaca Bay. However, the U.S. Fish and Wildlife Service has requested that a semi-quantitative assessment be conducted for the common loon.

Invertebrate-Eating/Bay

With the prevalence of fish in the marine waters of Lavaca Bay, there are few species of birds that avoid this resource in favor of deeper water habitat invertebrates. The exception are the bay ducks.

Bay Ducks

Bay ducks, or pochards, are diving ducks of the genus *Athya* (Bellrose 1980). Bay ducks found in Lavaca Bay include the canvasback, redhead, ring-necked duck, and lesser scaup (Alcoa 1995). In Lavaca Bay, these birds are typically rare or uncommon. However, canvasbacks are common during the winter, and lesser scaup are common during the fall and winter. None of these ducks are found in Lavaca Bay during the summer (Alcoa 1995).

Canvasback ducks feed about 80% on vegetation and 20% invertebrates and small fish, except wintering populations which shift their diet to predominately invertebrates (clams, snails, and insects) (Cottam 1939, Bellrose 1980). Lesser scaups wintering in Texas feed mostly on clams, crabs, and snails (Bellrose 1980). Although lesser scaup will feed at depths of 10–25 feet (Bellrose 1980), these and other diving ducks typically dive 2 to 10 feet for food (Kortright 1967). As is typical with bay ducks, canvasbacks and scaups winter in open, deeper water areas than dabbling ducks. No information is available on the size of the foraging ranges for wintering bay ducks, although the expanse of the bay environment in which they occur provides the opportunity for a large range.

Although bay ducks forage on marine invertebrates that may contain high concentrations of mercury, none of the bay duck species occur year-round in Lavaca Bay, and when present, they likely have large foraging ranges. The lesser scaup is not considered a good candidate as a receptor species because it does not occur year-round, and likely feeds over a large area of Lavaca Bay rather than concentrating in the Closed Area.

Other ducks, (e.g., mallards, mottled ducks), were not considered because of the high percentage of vegetation in their diet (Martin et al. 1951), and/or greater use of freshwater habitats (Terres 1987).

Invertebrate-Eating/Nearshore

This guild is represented by birds that feed almost exclusively on invertebrates (worms, insects, mollusks, crustaceans, etc.) in nearshore habitats such as *Spartina* marshes, shorelines, oyster reefs, exposed mudflats, surf, and other shallow water areas. In Lavaca Bay, two taxonomic groups of birds, the shorebirds and ibises, are in this guild.

Shorebirds

The Lavaca Bay area seasonally supports a wide variety of shorebirds, some in very large numbers. Thirty-six species of shorebirds have been recorded in the vicinity of the Closed Area (Alcoa 1995), most during the spring and fall migration periods. The most common of these migrants are the lesser golden-plover, greater yellowlegs, lesser yellowlegs, spotted sandpiper, ruddy turnstone, sanderling, western sandpiper, dunlin, and long-billed dowitcher. Sanderlings, in particular, can be found migrating through the area in the thousands. Some species, such as the black-bellied plover, American oystercatcher, greater yellowlegs, lesser yellowlegs, spotted sandpiper, long-billed curlew, ruddy turnstone, sanderling, western sandpiper, least sandpiper, dunlin, and long-billed dowitcher occur as common winter residents as well. Few shorebirds commonly breed in the Lavaca Bay area (Alcoa 1995). The exceptions include the Wilson's plover, killdeer, black-necked stilt, and willet (Alcoa 1995). Only the killdeer and willet are common year-round residents in Lavaca Bay (Alcoa 1995).

Most shorebirds feed by probing the mud for worms and insect larvae, or glean the mud surface for insects and other invertebrates. The sandpipers, willet, black-necked stilt, and dowitchers in particular, feed along the aquatic shorelines and mudflats. In Lavaca Bay, willets are most common in low and high marshes, but have been observed on oyster reefs (Alcoa 1997b). Several of the plover species such as the black-bellied plover, Wilson's plover, and killdeer, along with the long-billed curlew, feed commonly on insects in terrestrial habitats. Ruddy turnstones feed largely by turning over rocks looking for invertebrates. Oystercatchers specialize in feeding on bivalves such as oysters and mussels. In general, resident shorebirds confine their foraging to shoreline habitats (Ehrlich et al. 1988). The linear nature of most shorelines limit these birds to confined foraging areas. However, the willet feeds extensively in marsh habitats in the project area (Alcoa 1997b), which do not necessarily exhibit linear features. Nevertheless, the rich source of year-round food sources in these habitats, combined with the common year-round presence of these birds in Lavaca Bay, presumably indicates a relatively small foraging range for willets.

Shorebirds at greatest risk of exposure to mercury concentrations in Lavaca Bay are those that (1) feed on aquatic vertebrates and invertebrates, (2) concentrate their foraging activities in relatively small areas, (3) occur year-round in the study area, and (4) nest in the study area. Only the killdeer and willet meet all these criteria. Willets are generally more common than killdeers (Alcoa 1995), and likely derive a greater portion of their diet from the aquatic environment (killdeer derive a significant proportion of their diet from terrestrial environments [Terres 1987]). The risk of mercury exposure by willets is supported by U.S. Fish and Wildlife Service (1994a) data indicating higher mercury concentrations in the livers of willets than was measured in livers of other birds in the Alcoa study area. Based on the above factors, the willet was identified as a good receptor species to represent shorebirds and other wildlife that forage largely on aquatic invertebrates.

Ibises

The ibis family includes the white ibis, white-faced ibis, and roseate spoonbills. All three species breed in the vicinity of the Alcoa plant, including Dredge Island 3. However, the white-faced ibis is uncommon year-round, and is apparently more commonly associated with freshwater habitats (Terres 1987, Erlich et al. 1988). Both the white ibis and roseate spoonbill feed predominately on invertebrates such as crustaceans, mollusks, and aquatic insects (Palmer 1962, Terres 1987). They feed in both freshwater and marine habitats, however freshwater use may be more typical (Terres 1987). Either species is a good candidate to represent this taxonomic group, although the roseate spoonbill is apparently not as common as the white ibis during the breeding season (Alcoa 1995). The white ibis was not selected over the willet to represent this guild because it does not breed in the Closed Area, prefers to forage in fresh water over marine habitats, and individuals are unlikely to limit their foraging activity to the Closed Area (white ibis will feed 16–24 km away from nesting rookeries [Terres 1987]).

Fish- and Invertebrate-Eating/Nearshore

This guild includes bird species that forage on fish and invertebrates in the nearshore habitats. Killifish and gobies are found in the shallow, nearshore waters (Pattillo et al. 1995; Alcoa Draft RI) along with benthic shore crabs, fiddler crabs, small bivalves, and snails (Alcoa Draft RI). With the exception of filter-feeding bivalves, these groups of shallow-water prey have elevated concentrations of mercury (Alcoa 1997a). In Lavaca Bay, the herons and their allies are the common bird species likely to exploit these food resources.

Herons and Heron Allies

Twelve species of herons, egrets, and bitterns have been recorded in the Closed Area (Alcoa 1995), with the great blue heron, tricolored (Louisiana) heron, great egret, and snowy egret, being common year-round residents of Lavaca Bay. Herons and egrets feed on a wide variety of prey including fish, crustaceans, and aquatic and terrestrial vertebrates such as salamanders, snakes, and mice (Terres 1987). In the Alcoa study area, herons and egrets were much more commonly observed in estuarine environments than in freshwater habitats (Alcoa 1995). Although herons and egrets feeding in estuarine habitats feed largely (75–98 %) on fish, prawns and other crustaceans are an important dietary component for some species (Recher and Recher 1980).[1] Fish that are likely to be consumed by herons and are found in the shallow nearshore areas of Lavaca Bay include silversides, sheepshead minnows, gulf killifish, and code gobies (Pattilo et al. 1995).

Herons and egrets occur year-round in Lavaca Bay and nest at Dredge Island 3, outside of the Closed Area. The relatively large feeding ranges (5-30 km [Strong et al. 1997]) are likely to include areas outside of the Closed Area. These large feeding ranges may account for the lower mercury concentrations found in their eggs compared with local gulls, terns, pelicans, and

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[1] Hence, herons and their allies could be placed under both the fish-eating or fish-/invertebrate-eating guilds.

shorebirds (Alcoa 1995). Nevertheless, since local herons and egrets can potentially forage in areas where sediment mercury concentrations are elevated, some individuals may be subject to higher exposures of mercury. For this reason, the tricolored heron was selected as a receptor species to represent birds that feed on fish (and some invertebrates) in estuarine habitats.

Fish- and Invertebrate-Eating/Bay

Because of the lack of bird diet information specific to Lavaca Bay, no bird species have been identified to represent this guild. A portion of the diet of fish-eating terns may include free-swimming invertebrates (especially shrimp and squid). Also, a portion of the diet of invertebrate-eating bay ducks (e.g., scaup) may include fish, However, no bird species from Lavaca Bay is known to prey on relatively equal amounts of fish and invertebrates from bay habitats. Furthermore, any bird species that might represent this guild has already been evaluated in one of the previous guilds.

Raptors

Raptors (excluding osprey, which are piscivorous) can be exposed to mercury through consumption of other birds species containing elevated mercury concentrations. However, most raptors (hawks and owls) found on the Alcoa site feed on terrestrial prey (Terres 1987). The one exception is the peregrine falcon that, seasonally feeds heavily on shorebirds (Terres 1987). The peregrine falcon occurs in the Lavaca Bay area as an uncommon migrant during the spring and fall, and a rare winter resident (Alcoa 1995). Its presence likely coincides with that of the shorebirds. Because of its low occurrence, large foraging area, and the likelihood its diet is predominated by prey that do not feed heavily in the Closed Area (e.g., migrant shorebirds and terrestrial birds), the guild does not contain species that would be good candidate receptors for RWC evaluations.

2.1.2. Selection of Indicator Species

Through the guild evaluation process, three species of birds were selected as receptors (representative species) for further evaluation for injury to birds. The willet was chosen to represent birds that feed on invertebrates in the nearshore habitats. Stenzel et al. (1976) found willets on California coastal areas to feed largely on surface-dwelling snails, small bivalves, tube-dwelling amphipods, algal-dwelling amphipods, and small shore crabs, but in Texas, willets are reported to feed on minute crabs, mollusks, fish fry, small fish, insects, and worms (Oberholser 1974), but specific dietary studies are lacking. Willets are year-round residents that nest and forage (in localized areas) in the vicinity of the Closed Area (Alcoa 1997b) and they have been reported to have elevated concentrations of mercury in the liver (USFWS 1994a). In the Closed Area, willets were found to be common in the marshes of Dredge Island 1 and other larger estuarine high and low marsh habitats. Willets were also observed on an oyster reef immediately north of Dredge Island 1, but these areas are considered marginal feeding habitats for this species (Alcoa 1997b).

Tricolored herons were chosen to represent bird species that forage on both fish and epibenthic invertebrates (small crabs and snails) in the nearshore habitat. As there are no data on the diets of tricolored herons in Lavaca Bay, this heron may feed predominately on fish in the nearshore environment. In Florida estuaries, tricolored herons were found to feed 84% on fish and 16% on prawns (Recher and Recher 1980), and 96% fish (Jenni 1969). In these studies, the most common fish species eaten were sailfin molly, flagfish, mosquitofish, topminnows, and killifish. In New Jersey, tricolored herons fed on fish in the 2–8 cm range (Willard 1977).

Tricolored herons forage an average of 5 to 13 km from nesting rookeries (depending on the annual rainfall), and on selected sites that averaged 3 km apart on consecutive feeding days (Strong et al. 1997). In the Closed Area, tricolored herons were found scattered about the marsh areas of Dredge Island 1, larger *Spartina* marshes along the mainland, and the oyster reef immediately north of Dredge Island 1 (Alcoa 1997b). Compared to other herons, tricolored herons usually feed in deeper water (20-25 cm), commonly up to their leg or belly feathers (Jenni 1969). There is also information on mercury concentrations from eggs collected at nesting rookeries several miles southwest of the Closed Area.

The Forster's tern was selected as a candidate receptor species to represent bird species that feed predominately on fish in the open water bay environment. The Forster's tern nests in the vicinity of the Closed Area and is common year-round. While this bird may forage over fairly large areas, birds nesting at Dredge Island 2 have elevated concentrations of mercury in their tissues.

2.2 Quantification of Exposure

For assessing exposure to wildlife receptors, the exposure must be expressed as a dose which is expressed in a normalized manner as mass of chemical per body weight of the receptor per day (with a standard unit of mg/Kg/day). This form of the dose equation is standard and consistent with the manner that toxicological studies are summarized and reported in the literature. Other means for expressing exposure are in terms of concentration in the diet (mg/Kg) or in the exposure media (mg/Kg for soil or sediment and mg/L in the diet) that relates to known or observed adverse effects. Since the principle route of exposure is bioaccumulation, exposure can be expressed as either a dose and/or a concentration in food. A dose can also be expressed as an equivalent food concentration, and vice versa, once intake rate and body weight are known.

For quantification of birds, exposure will be expressed as a dose with equation 1:

$$Dose = \frac{Conc \times IR \times AUF}{BW}$$

where: Dose = chemical dose normalized to daily intake and body weight of the receptor (mg/Kg/day)
Conc = chemical concentration in food (mg/Kg)
IR = prey ingestion rate (Kg/d)
AUF = area-use factor (for chronic exposure only)
BW = wildlife receptor body weight (Kg)

For the representative bird populations evaluated for RWC in Lavaca Bay, the concentration in the food was measured directly in the remedial investigation program under Volume B2e: Bay System Fish and Bird Prey Item Study (Alcoa, Draft RI). In the Prey Item Study, analytical data were collected on 18 different prey species at 57 different sampling stations for three different habitats of concern in Lavaca Bay (open water, marsh/mudflat, and oyster reef). This includes prey items collected from 14 distinct marsh/mudflat habitats, four different open water areas, and 10 distinct oyster reef areas.

An area use factor (AUF) is important if the exposure area comprises only a portion of the home range (or feeding range) for the receptor. For purposes of reasonable worse case, it is assumed that there is a sufficient geographic feeding area that is impacted such that bird populations or significant portions of resident bird populations could be exposed. Area use will also be implicit in the method for estimating an exposure concentration. As described above, prey concentrations will be combined over adjacent or contiguous habitats that comprise a likely feeding area for birds. Therefore, an AUF of 1 is appropriate.

Overall food ingestion rates were determined based on specific information on the feeding ecology (i.e., what birds eat) of each species and how much they eat. The latter can be determined from either feeding studies or allometric equation on basal metobolic rate (U.S. EPA, 1993). Exposure to both inorganic mercury and methyl mercury were considered. The particular prey present within a specific habitat type was a key consideration in identifying appropriate diet. Specific dietary information for each representative bird population is provided below.

Willet. Willets are shore birds that feed principally on invertebrates in shallow water areas. The important habitat for willets include principally marsh/mudflats, although willets may feed on oyster reefs, when exposed at low tide. Prey item data for marsh/mudflat habitat types were used to estimate willet dietary exposures. The types of prey items typically consumed by willets from marshes/mudflats were identified from a literature review and professional judgment of the Trustees.

The willet diet primarily consists of invertebrates, with fiddler crabs as the principle food item consumed (Howe, 1982). No information from the scientific literature was available on difference in prey items in the diet relative to specific habitat types. In the Prey Item Study, fiddler crabs were collected in marsh/mudflat habitat. Although the literature was not specific, it was assumed that approximately 90% of the willet diet in marsh/mudflats was comprised of fiddler crabs (best professional judgment) and 10% mud crabs.

Willets have a small home range during the breeding season. Accordingly, willet exposures to mercury could be evaluated over small subareas of contiguous and adjacent habitats that could be used by subpopulations of willets in Lavaca Bay.

Tricolored Heron. The tricolored heron is a representative wading bird that feeds in marsh/mudflat and oyster reef habitat. The tricolored heron feeds predominantly on fish (about 95%) and to a much lesser degree on invertebrates such as shrimp (Kent, 1986). These dietary fractions were assumed in quantifying exposure for tricolored herons. In marsh/mudflat habitat, multiple fish species and shrimp were sampled in the Prey Item Study. Because the relative proportions of fish species comprising the diet of the tricolored heron at the Site are not known, all fish species are assumed to contribute equally to the heron diet. In oyster reef habitat, the tricolored heron diet is assumed to be comprised entirely of fish (i.e., naked goby). The tricolored heron has a much larger home range than the willet which may include large portions of contiguous low marsh and oyster reef habitats in Lavaca Bay.

Forster's Tern. The Forster's tern is a representative pelagic (open water) feeding bird with a much larger home range than willets. Terns may travel several kilometers from their nests to forage and, therefore, Lavaca Bay represents only a fraction of a tern's potential feeding range. The major prey items occurring in Lavaca Bay that would likely be consumed by Forster's terns are Bay anchovy, Gulf menhaden, and silversides (McAtee and Beal, 1912; Reed, 1985).

These prey items were collected in the open water areas of Lavaca Bay. There is no information on the relative proportion that each species contributes to the Forster's tern's diet. Because the Forster's tern has a large home range, its feeding range could encompass an area larger than Lavaca Bay. For reasonable worse case purposes, it was assumed that subpopulations of terns could feed regularly in one of more areas of interest within Lavaca Bay.

Other factors to consider for calculating dose from equation 1 include the ingestion rate (IR) and body weight (BW). A summary of these variables with dietary composition by habitat and prey species is provided Table 1.

2.3 Mercury/Methylmercury Dose-Response Assessment

A dose-response assessment for mercury was completed as a part of problem formulation process in support of the Baseline Risk Assessment for Lavaca Bay (Alcoa, draft BLRA). The dose-response assessment involves a review of literature derived ecological effects data, which identify toxicity reference values (TRVs). TRVs can be expressed two different ways: as a chemical concentration in the exposure media, such as food, water or soil/sediment, or as a dose (mg chemical/Kg body weight per day). For assessing potential injury to birds, the TRVs are normally expressed as a dose. Given assumptions on intake and body weight for a known dose, a TRV can be expressed as a threshold concentration in the diet. Toxicological data were reviewed to select the appropriate TRVs to evaluate potential injury to birds based on chronic-type exposures.

Table1: Exposure Parameters for Representative Bird Populations

Parameter	Definition	Value	Bird Species	Reference	Habitat/Diet
IR	Prey ingestion rate (Kg/d)	0.108	Willet	EPA, 1993	Marsh/Mudflat: Crab Species - 90% Fiddler Crabs 10% Mud Crabs
		0.087	Foresters Tern	EPA, 1993	Open water: Fish Species - 75% Bay Anchovy 25% Gulf menhaden
		0.1125	Tricolored Heron	EPA, 1993	Marsh Mudflat (85%): 5% juv. blue crab 95% Fish

					80% Killifish 7.5% silverside 7.5% sheepshead 5% mullet Oyster Reef (15%): 5% juv. blue crab 95% Fish 70% gobi 30% silverside
BW	Body weight (Kg)	0.215 0.158 0.375	Willet Foresters Tern Tri. Heron	Dunning, 1993 Dunning, 1993	

2.3.1 Dose Response Methodology

The literature was reviewed to find information on the toxicity of mercury (inorganic and methyl mercury) to birds. The review began with information provided in summary documents on mercury and these metals were used first. For example, the Fish and Wildlife Service's document *Mercury Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review* (Eisler, 1987), the *Toxicological Profile for Mercury* (ATSDR, 1994), and the Oak Ridge Database (Sample et al., 1996) were examined to identify toxicological values. In addition, other databases, such as the Registry of Toxic Effects of Chemical Substances (RTECS) (1997), was consulted for additional toxicity data. With the exception of any EPA documents that may have been consulted, original research papers were obtained for all toxicological studies identified in summary documents and textbooks. Supplemental database searches were also performed to obtain more complete information on mercury toxicity because the data identified for fish and wildlife can be limited in the summary documents that were reviewed.

In selecting TRVs, chronic studies with effect endpoints addressing reproduction and development were given the highest priority, followed by studies addressing growth, survival, and systemic effects. The LOAEL and NOAEL from chronic studies were identified, when available. When a NOAEL for mercury was not available from a study, one was not estimated using uncertainty factors. Instead, measured NOAELs from similar studies were considered for the same endpoint. Both the LOAEL and NOAEL were used in assessing potential injury. The range from the NOAEL to the LOAEL is desirable to provide an evaluation of the uncertainty associated with the effect threshold dose.

All studies identified from the literature search were evaluated based on dosing regime, dosing medium, and the relevance of toxic effect endpoints. Those studies with abnormal dosing regimes (discussed below) were given low priority and only used for assessing injury if other more appropriate studies were not available. Dosing regime was defined as the method of delivery of the dose; that is, ingestion, gavage (use of a stomach feeding tube), or intraperitoneal injection. The more acceptable dosing regimes (i.e., those that more closely approximated environmental exposures) include normal ingestion of food or water. Animal dosing regimes that were not considered representative of environmental exposure scenarios included gavage and intraperitoneal injections..

The dosing medium was also defined in terms of the form of mercury that was used. For example, acceptable dosing media for mercury included inorganic mercury salts, such as mercuric chloride, as well as organic forms of mercury, such as methyl mercury (methyl mercury chloride, methyl mercury hydroxide, dimethyl mercury, and biologically incorporated methyl mercury).

Finally, due to the lack of fish and wildlife toxicity studies for the specific receptors present in Lavaca Bay, data from surrogate species were used for all receptors that were evaluated. Surrogate species were selected to be as similar to the representative receptor as reasonably possible. Some wildlife studies available in the scientific literature could not be used to assess relative toxicity because mercury effects were summarized based on chemical residue levels in animal tissue, and a clear dose-response relationship was not identified. Toxicological effects data (doses) were more readily available from studies on domestic and laboratory animals, such as rats, mice, chickens, mallards, and quail. A summary of TRVs obtained in the literature review are provided in Attachment A.

2.3.2 Selected Dose-Related TRVs.

For the representative bird populations assessed for RWC, the lowest appropriate LOAEL and highest appropriate NOAEL were selected as representative TRVs. The LOAEL and NOAEL were considered appropriate, as stated above, when the information was based on the appropriate endpoint being evaluated, the dosing regime, and media.

For mercury, a range of appropriate LOAEL and NOAEL values was considered. TRVs were selected from all available bird data when the toxicological endpoints for these surrogates included mortality and reproductive effects, such as reduced hatchability and eggshell thinning. The mercury TRVs selected for evaluating risks to wildlife receptors are shown in Table 2.

Table 2: Selected TRV's for Assessing Injury to Birds

TRV	Methylmercury (mg/Kg/day)		Inorganic Mercury (mg/Kg/day)	
NOAEL	0.41	a	0.41	d
LOAEL	0.67	b	0.83	d
LD50	5	c	26	c

NOTES:
a - Hill and Soares, 1984
b – Lundholm 1995
c - Eisler 1987
d - Hill and Schaffner 1976

2.3.3 Dietary TRVs

TRVs can also be expressed as a concentration in food below which negligible injury (i.e., below a NOAEL) or low injury (below a LOAEL) is likely. Dietary TRVs are calculated for a given dose-response factor once receptor-specific assumptions of exposure are understood. This involves substituting a NOAEL or LOAEL for 'Dose' in equation 1 and re-arranging terms to solve for concentrations (TRV) with equation:

$$TRV_{NOAEL} = \frac{NOAEL \times BW}{IR \times AUF}$$

or

$$TRV_{LOAEL} = \frac{LOAEL \times BW}{IR \times AUF}$$

Table 3 presents the dietary TRVs for the representative bird populations assessed for reasonable worse case. Dietary TRVs must be interpreted in a manner similar to a dose-response type assessment. For RWC purposes, it represents the average (95% UCL on the mean) of the diet of the receptor. Thus, the dietary TRV represents a weighted-average concentration across the species that are important within the diet of the receptor. For example, for RWC purposes this was assessed in a conservative manner assuming the diet consists principally of fiddler crabs (90%) and mud crabs (10%) for the willet from marsh/mudflat-type habitats; or bay anchovy (70%) and gulf menhaden (30%) for the Foresters tern in open water type habitats.

3.0 CALCULATION OF SEDIMENT-EFECT CONCENTRATIONS FOR BIRDS

A dietary TRV can be expressed as a sediment-effect concentration with the use of a biota-sediment factor (BSF). Similar to a biota-sediment accumulation factor (BSAF), a BSF within this assessment relates the concentration of the chemical of interest (methylmercury) in the diet of a receptor to the total mercury (principally inorganic mercury) concentration in sediment. A sediment-effect concentration ($Conc_{sed}$) is then calculated with the equation:

$$Conc_{sed.} = \frac{TRV_{diet}}{BSF}$$

Unlike a BSAF, the BSF has units of mg-wet weight methylmercury in diet / mg-dry weight total mercury in sediment. A wet-weight unit must be used since the dietary NOAELs and LOAELs used for assessing injury are wet-weight estimates. Estimated sediment-effect concentrations are provided in Table 4. An overview of the sediment-effect concentrations by habitat is provided below.

Open Water Habitats
The Foresters Tern was the representative receptor for open water-type habitats. Foresters Tern feed principally on small fish. For reasonable worse case purposes it was assumed they feed 75% on bay anchovies and 25% gulf menhaden. The predominate form of mercury (>95%)

in these species is methylmercury. Measured methylmercury BSFs for these species range from 0.13 to 0.19, for Gulf menhaden and bay anchovies respectively, with a weighted average (based on diet) BSF of 0.175. The methylmercury dietary TRVs for the Foresters Tern are 0.7 ppm for the NOAEL and 1.2 ppm for the LOAEL (Table 3). The sediment-effect concentrations using the weighted average BSF range from 4.3 ppm using the NOAEL to 6.9 ppm for the LOAEL. Units are mg/Kg-dry weight sediment.

Oyster Reef Habitats
The tricolored heron is the representative receptor for oyster reef-type habitats. On oyster reef type habitats, tricolored herons feed principally on small fish and some crustaceans. For reasonable worse case purposes it was assumed they feed 95% on fish (70% gobies and 25% Atlantic silverside) and 5% on juvenile blue crabs. The predominate form of mercury (>95%) in these species is methylmercury. Measured methylmercury BSFs for these species range from 0.19 (silversides) to 0.56 (gobis), with a weighted average BSF of 0.44. The methylmercury dietary TRVs for the tricolored heron range from 1.4 ppm for the NOAEL to 2.2 ppm for the LOAEL (Table 3). The sediment-effect concentrations using the weighted average BSF range from 3.1 ppm using the NOAEL to 5 ppm for the LOAEL.

Fringe Marsh/Mudflat Habitats
The tricolored heron and the willet are the representative receptors for fringe marsh-type habitats. In fringe marsh habitats, tricolored herons feed principally on small fish and some crustaceans. For reasonable worse case purposes it was assumed they feed 95% on fish (80% killifish, 7.5% sheepshead, 7.5% Atlantic silverside, and 5% mullet) and 5%on juvenile blue crabs. The predominate form of mercury (>95%) in these species is methylmercury. Measured methylmercury BSFs for these species range from 0.15 (mullet) to 0.75 (killifish), with a weighted average BSF of 0.64. The methylmercury dietary TRVs for the Tricolored heron range from 1.4 ppm for the NOAEL to 2.2 ppm for the LOAEL (Table 3). The sediment-effect concentrations using the weighted average BSF range from 2.1 ppm using the NOAEL to 3.4 ppm for the LOAEL.

Willets feed principally on crabs and other small invertebrates. For reasonable worse case purposes it was assumed they feed 90% on fiddler crabs and 10% on mud crabs. The predominate form of mercury (>90%) in these species is methylmercury. Measured methylmercury BSFs for these species range from 0.31 (mud crabs) to 0.35 (fiddler crabs), with a weighted average BSF of 0.34. The methylmercury dietary TRVs for the willet range from 0.8 ppm for the NOAEL to 1.3 ppm for the LOAEL (Table 3). The sediment-effect concentrations for the willet using the weighted average BSF range from 2.4 ppm using the NOAEL to 3.8 ppm for the LOAEL.

4.0 COMPARISON OF SEDIMENT-EFFECT CONCENTRATIONS FOR BIRDS AND FISH BY HABITAT

Open Water Habitats
The sediment-effect concentrations for Foresters tern range from 4.3 ppm using the NOAEL to 6.9 ppm for the LOAEL. These concentrations are higher than the sediment-effect concentrations for open water calculated for fish. Since the sediment threshold for fish injury is lower than that for birds, it is assumed that the areal extent of fish injury within open-water-type habitats exceeds that for birds. Since, for RWC purposes, injury that results from bioaccumulation of mercury is assumed the greater of injury to birds or fish populations, quantification of potential bird injury in open water-type habitats is not warranted.

Oyster Reef Habitats
The sediment-effect concentrations for tricolored herons in oyster-reef type habitats range from 3.1 ppm using the NOAEL to 5 ppm for the LOAEL. These concentrations are higher than the sediment-effect concentrations for oyster reef-type habitats calculated for fish. Since the sediment threshold for fish injury is lower than that for birds, it is assumed that the areal extent of fish injury within oyster reef -type habitats exceeds that for birds. Since, for RWC purposes, injury that results from bioaccumulation of mercury is assumed the greater of injury to birds or fish populations, quantification of potential bird injury in oyster reef-type habitats is not warranted.

Fringe Marsh/Mudflat Habitats
The sediment-effect concentrations for tricolored herons were lower than for willets in fringe marsh-type habitats, ranging from 2.1 ppm using the NOAEL to 3.4 ppm for the LOAEL. These concentrations are higher than the sediment-effect concentrations for fringe marsh/mudflat-type habitats calculated for fish. Since the sediment threshold for fish injury is lower than that for birds, it is assumed that the areal extent of fish injury within fringe marsh-type habitats exceeds that for birds. Since, for RWC purposes, injury that results from bioaccumulation of mercury is assumed the greater of injury to birds or fish populations, quantification of potential bird injury in fringe marsh-type habitats is not warranted.

5.0 SUMMARY AND CONCLUSION

The assessment of potential injury for bioaccumulation of mercury in Lavaca Bay used a reasonable worse case approach based on the greater of injury for bird or fish populations. Injury was assessed for birds by converting a toxicity reference value (TRV) for representative receptors to an equivalent dietary concentration and then converting the dietary TRV to a sediment-effect concentration. Similarly, for fish critical tissue concentrations were converted to a sediment-effect concentration. These served as a basis for comparison to determine whether birds or fish had a greater potential magnitude of injury. The resulting analysis determined that, for each habitat, the sediment-effect concentration was lower for fish indicating that injury to fish was spatially greater than the equivalent injury to birds. The types of injuries to birds and fish from mercury are basically similar (i.e., behavioral, reproductive, and early life history effects), but fish have a lower sediment-effects concentration threshold than do birds. Therefore it is unlikely that birds would have a greater severity of injury in the areas above their sediment-effects concentrations than fish. Thus, further quantification of potential bird injury in Lavaca Bay was not warranted. This finding is not intended to suggest there is no injury to bird populations. As explained above, the injured areas for birds is within the injury areas identified for fish and the severity of injury for fish within those areas is greater than that for birds; therefore, the injury quantification for fish captures the greater of the injury. The Trustees are confident that the bird injury in these habitat areas will be addressed by restoration projects to offset the higher fish injury within these same habitats.

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